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Solar Radiation Affects Radiant Temperatures of a Deer Surface

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Variation in the effective radiant temperature (ERT) of a deer hide, when sunlit and shaded, was measured with an infrared radiometer. The mean decrease in ERT was 18.3° C. in 120 seconds after shade was applied. The authors conclude that missions for deer detection by an airborne thermal infrared scanner should be conducted during periods of no direct-beam solar radiation, that is, sunset to dawn.
Keywords: Deer, infrared, thermal scanner, solar radiation.

The experiment discussed here was an outgrowth of a broader study of the environmental factors that affect thermal radiation from mule deer (Odocoileus hemionus hemionus) in winter,[3] as a basis for determining the detectability of these animals by an airborne thermal infrared scanner. Detection of deer by this method depends on the difference in effective radiant temperature (ERT) between the animals and their background. One factor which caused large, rapid changes in the ERT of the deer in that study was shading from various sources, including cloud passage. Abrupt decreases and increases in excess of 15° C. were observed on several occasions, apparently due to this effect.

The purpose of this experiment was to determine the magnitude and rate of change in ERT of a simulated deer surface which could occur as a result of shading.

Methods

A tanned, furred mule deer hide was used to simulate a live deer surface. It was supported horizontally 18 inches above a gravel surface, outdoors. ERT measurements were made at a distance of 38 inches with a Barnes PRT-5 Infrared Radiometer[4] aimed at a point near the center of the hide. The resulting field diameter on the deer hide was about 1.3 inches. The radiometer output was recorded continuously on a strip-chart recorder, running at 2 inches per minute.

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[3]Parker, H. Dennison, Jr. Airborne infrared detection of deer. Ph. D. thesis, Colorado State University, Fort Collins. 186 p. 1972.

[4]Trade and company names are used for the benefit of the reader, and do not imply endorsement or preferential treatment by the U. S. Department of Agriculture.

A "run" consisted of a time period which began when the deer hide was abruptly shaded with a piece of plywood. The plywood was held between the sun and the deer hide approximately 8 feet from the observed portion of the hide. Shading was continued until the radiant temperature of the hide had become stable. Then the shade was removed and the ERT of the hide was monitored until stability was again reached.

Three runs were made. The investigator doing the shading remained in the same position relative to the deer hide to prevent any change in infrared radiation falling on the deer hide from surrounding objects. The air temperature beneath the hide was continuously monitored by an Atkins temperature monitoring system.

The sky was clear on the day of the test; air temperature underneath the hide varied from 2.3° to 2.5° C., and windspeed was estimated at 10 to 15 miles per hour.

Results

Effective radiant temperatures stabilized in approximately 120 seconds after shading in all three runs (fig. 1). Decreases of 19.9°, 17.2°, and 17.3° were recorded for runs 1, 2, and 3, respectively. After removal of the shade, the radiant temperatures increased at a rate similar to the decay rate and stabilized at approximately the same temperatures which existed prior to shading (fig. 2).

The small, erratic fluctuations in ERT in the chart recording (fig. 2) represent forced convective cooling caused by wind, and were more pronounced at higher ERT values. This difference in wind effect between high and low ERT values is reasonable, considering that the rate of heat transfer was proportional to the thermal gradient from the radiating surface to the air. At high ERT values, the thermal gradient between hair surface and air was greater than at low ERT values.

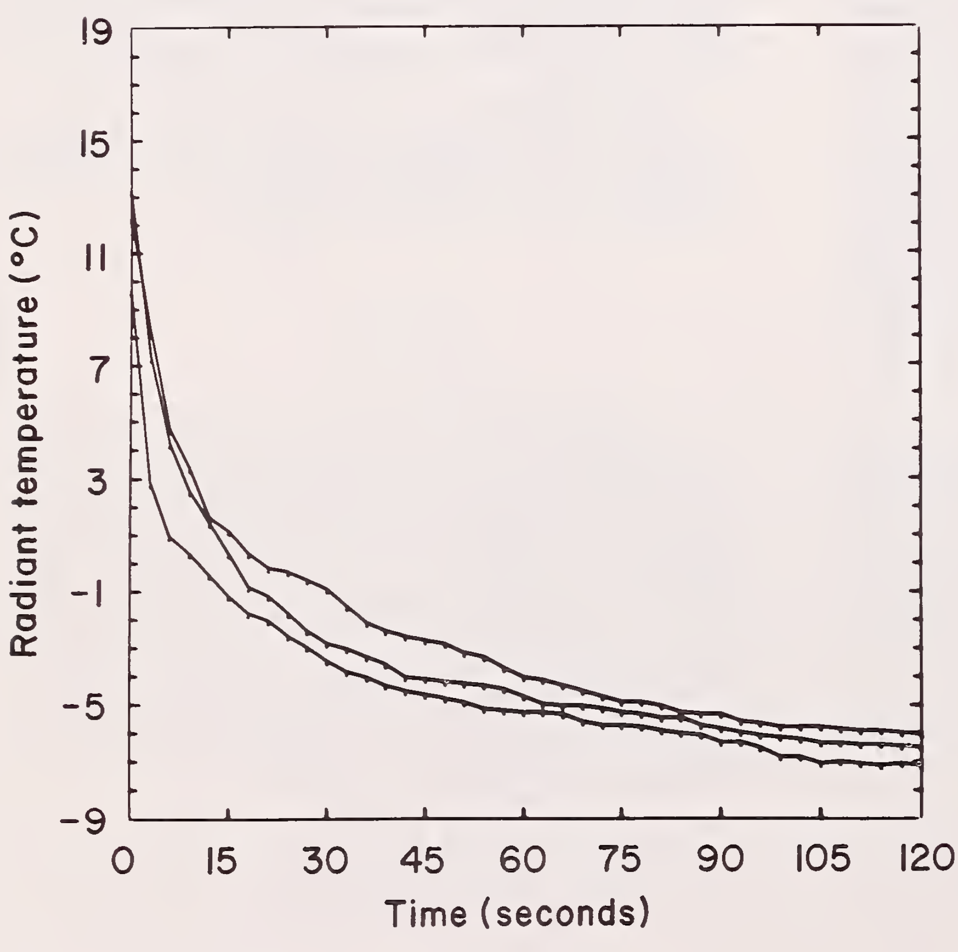

Figure 1.—Radiant temperature decay, sampled at 3-second intervals. Shade was applied at time = 0.

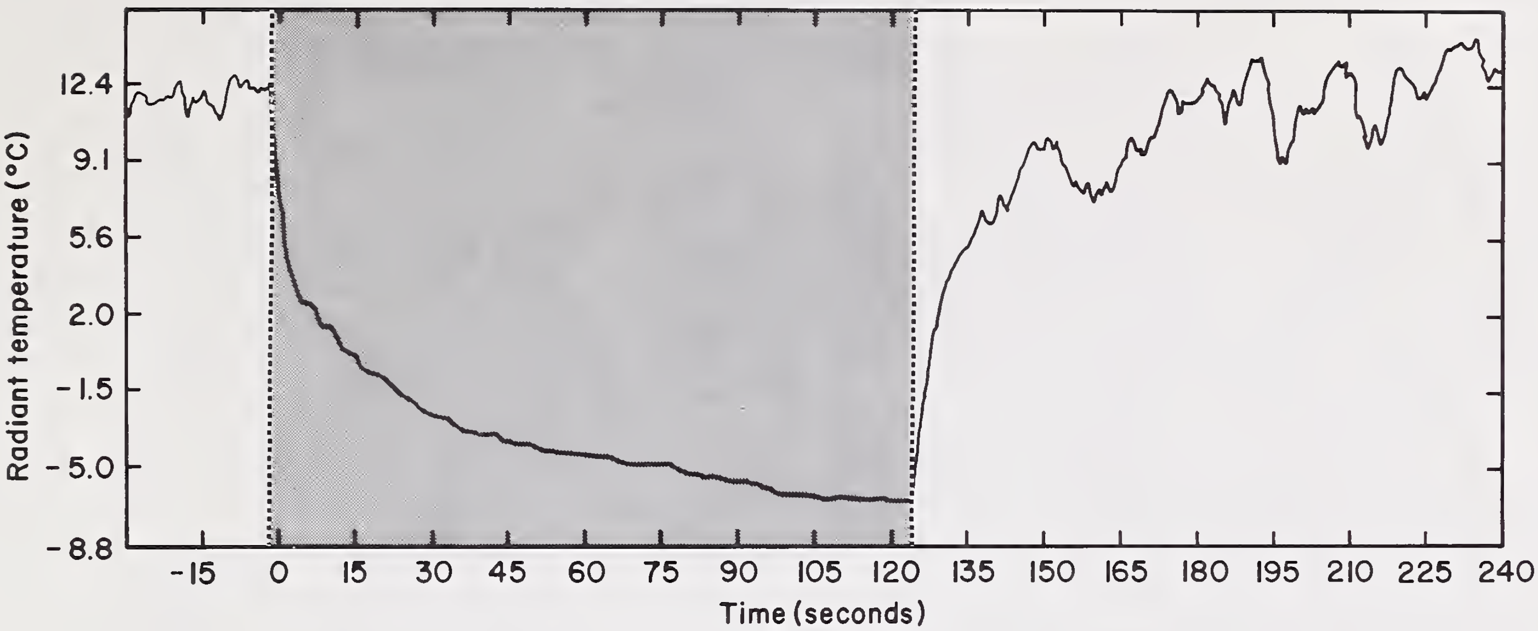

Figure 2.—Chart recording of radiant temperature for run No. 1. Shade was applied at time = 0 and removed at time = 120 seconds. Curve shapes were similar for all three runs.

Conductive heat transfer from the fur surface to the skin has been shown to occur primarily in the air trapped between the hairs.[5] The approximate quantity of energy transferred in this manner is given by:

$$H = K(\Delta T/\Delta Z) \qquad [1]$$

where

H = conductive heat transfer (cal $cm^{-2} min^{-1}$)

K = thermal conductance of the conducting medium

ΔT = temperature difference (° C.)

ΔZ = distance (cm)

If $K_{fur} \leq K_{air}$, then the thermal conductance of air, 3.58 X 10^{-3} cal $cm^{-1} min^{-1}$ °$C.^{-1}$, may be used for K. ΔT averaged 18° C., assuming (1) the emissivity ϵ of fur is very nearly 1.0; thus radiant temperature $\simeq$ actual temperature, and (2) skin temperature = air temperature when shaded. ΔZ was approximately 2 cm.

Using these values in equation [1] gives an initial rate of conductive heat transfer of 0.0322 cal $cm^{-2} min^{-1}$.

Radiant heat transfer is 4.2 mw $ster^{-1} cm^{-2}$ at a radiant temperature of 18° C., assuming $\epsilon = 1.0$.[6] Multiplying by 2π to get total hemispherical radiation, and converting units, the rate of radiant heat transfer is 0.3781 cal $cm^{-2} min^{-1}$.

Thus, the initial rate of conductive heat transfer is less than one-tenth the radiant heat transfer rate. Total heat transfer by each process could be obtained by integration of each rate over the 120-second time interval. Although radiation from a live deer is considerably more complex, the response of the fur layer to changing solar radiation may be reasonably expected to be similar to that shown in this experiment.

[5] *Hammel, H. T. Thermal properties of fur. Am. J. Physiol. 182: 369-376. 1955.*

[6] *mw $ster^{-1} cm^{-2}$ is an abbreviation for milliwatts per steradian per square centimeter, which are units for radiant power emission (milliwatts), through a unit solid angle (steradian), from a surface 1 square centimeter in area.*

Discussion

The difficulty of obtaining radiation data under cloudy conditions, with remote sensors operating in the reflective wavelength bands, is well known. This experiment demonstrates a degree of variability in emitted radiation which can occur in the longer (8 to 14 micrometer) wavelengths, as a result of shading. A quantitative, general description of this effect in terms of the various environmental influences and specific surface characteristics must await further study. However, these results confirm the existence of a shading effect large enough to be of importance in an airborne thermal infrared scanning operation.

In particular, detection of big game animals by their thermal radiation will probably depend on thermal contrasts between the animals and their background which are considerably smaller than the temperature differential found in this study due to shading alone. Therefore, in terms of the effects of solar radiation on ERT, conditions for thermal detection of wild, big game animals would appear to be optimum during those periods when solar radiation is uniform. This criterion may be met by conditions of either (1) no cloud shadow on the flight line, or (2) no direct-beam solar radiation, that is, 100 percent cloud cover, or the period from sunset to sunrise, including crepuscular hours and hours of darkness. Since shadows may be cast by environmental objects other than clouds, the latter situation is probably preferable. Night or total cloud cover is probably desirable from the standpoint of wind effect, also, since variability of deer ERT due to wind decreased under conditions of no direct-beam solar radiation.